Persistent scatterer interferometry based on COSMO-SkyMed imagery

Pietro Milillo[1], Agram Piyush Shanker[2], Stefania Pascale[1],Carmine Serio[1], Francesco Sdao[1]

[1] University of Basilicata, School of Engineering, Potenza, Italy; pietro.milillo@unibas.it
[2] NASA - Jet Propulsion Laboratory (JPL), Pasadena, California, USA

Abstract. This work illustrates the potential of InSAR Persistent Scatterer (PS) operative framework developed at Univeristy of Basilicata using X-band SAR (Synthetic Aperture Radar) data acquired from COSMO-SkyMed Italian constellation for a detailed detection and characterization of millimetric terrain motion at local scale in Basilicata.

Keywords. SAR, COSMO-SkyMed, Persistent Scatterers, Time Series.

1. Introduction

The finer spatial resolution of X-band InSAR applications appear very promising for monitoring single man-made structures (buildings, bridges, railways, highways and dams). In this case it is expected that many more man-made and natural targets will behave as persistent scatterers, it should be possible to estimates displacement rates with a number of SAR scenes significantly lower than higher wavelength sensors, moreover higher frequency increase both LOS displacement and very low displacements rates detection.

The aim of this work is to introduce the operative framework developed at University of Basilicata within the School of Engineering proposing some possible example of surface deformation like subsidence and landslide in Basilicata territory.

Dataset consist of an interferometric stack of COSMO-SkyMed HIMAGE data acquired starting from 2010. COSMO-SkyMed is a Dual-Use (Civilian and Defence) End-to-End Earth Observation System aimed at establishing a global service supplying provision of data, products and services relevant to a wide range of applications. The system consists of a constellation of four LEO mid-sized satellites, each equipped with a multi-mode high resolution SAR operating at X-band.

2. Methods

Inteferometric time series analysis technique used is the InSAR persistent scatterer (PS) method for analyzing crustal deformation in non-urban environments [1]. This method is based primarily on phase characteristics and finds low-amplitude pixels with phase stability in order to identify PS pixels in a series of interferograms. PS method finds scatterers with stable phase characteristics independent of amplitudes associated with man-made objects, and is applicable to areas where conventional InSAR fails due to complete decorrelation of the majority of scatterers.

Considering a set of DInSAR interferograms the phase component can be written as the sum of 5 terms:

$$\varphi_{int,x,i} = \varphi_{def,x,i} + \Delta\varphi_{,x,i} + \varphi_{atm,x,i} + \Delta\varphi_{orb,x,i} + \varphi_{n,x,i}$$

Where φ_{def} is the phase change due to movement of the pixel in the satellite line of site (LOS) direction $\Delta\varphi\varepsilon$ is the residual DEM error, φ_{atm} is the the difference in atmospheric retardation between passes, $\Delta\varphi_{orb}$ is the residual phase due to orbit error and φn the noise term due to variability in scattering from the pixel, thermal noise and coregistration errors. In order to estimate φ_{def}, Framework used is StaMPS (Stanford Method for Persistent Scatterers) which can be considered a collection of spatial and temporal filtering algorithm that allow to estimate each phase component of the radar signal.

StaMPS PS selection technique outperforms the other PS algorithms [2] and succefully identifies more PS pixels in non-urban vegetated terrain [1,3]. The Generic InSAR Analysis Toolbox (GIAnT) framework is used as a direct comparison of performance of the StaMPS algorithm.

GIAnT [7] is an open source toolbox for implementing time-series InSAR analysis techniques in a common framework. GIAnT already includes implementations of the SBAS [Berardino et al.,], NSBAS [Lopez-Quiroz et al.,] and MInTS [Hetland et al.,]. Moreover, GIAnT also includes support

for using weather models and reanalysis to reduce the effects of stratified troposphere in the inferred time-series. Analysis of the dataset using GIAnT will allow for direct comparison of time-series results using different approaches.

3. Dataset

Dataset consist of three interferometric stack of COSMO-SkyMed MapItaly data on Pertusillo dam acquired starting from 2011 and one InSAR stack on Potenza acquired starting from 2010. More information about datasets can be found in Table 1

COSMO-SkyMed constellation is composed by four satellites so this means that each satellite uses only one beam allowing a temporal baseline coverage of 16 days.

The MapItaly project was developed by ASI and the Department of Civil Protection, with e-GEOS support. The project goal is to provide a mapping of the entire Italian territory with the COSMO-SkyMed interferometric mode StripMap HIMAGE (HH polarization), in either right Ascending and right Descending orbit (Fig. 1). For an HIMAGE coverage at Italian latitude four overlapped different beams are needed (Table 2)

Since the COSMO-SkyMed constellation is composed of 4 satellites, this mechanism requires to assign a beam to each satellite, thus allowing an interferometric coverage with a time baseline of 16 days.

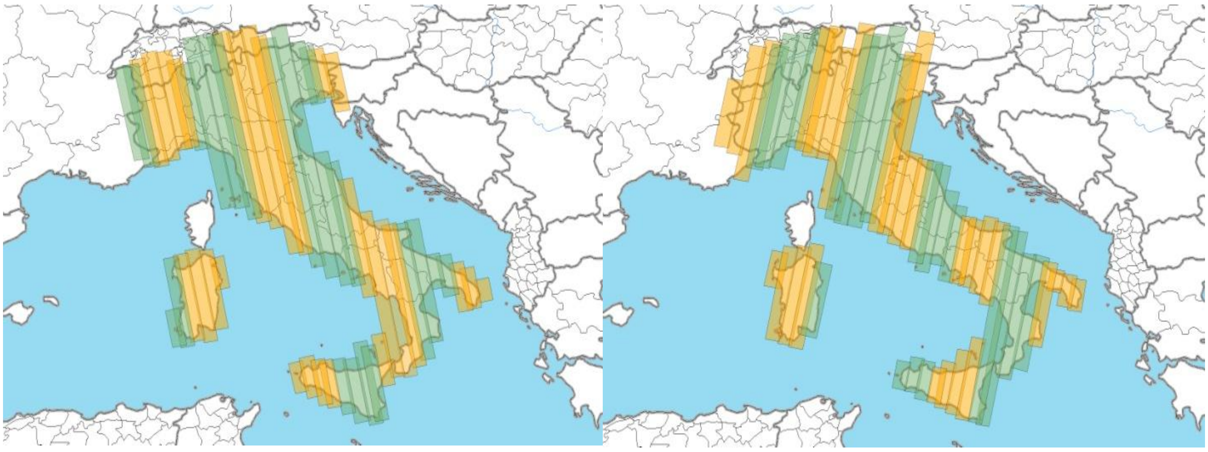

Figure 1. MapItaly coverage, right-ascending and right-descending

Dataset	N° Images	Date
Potenza_RD_HI_16	67	Nov 2010 – Feb 2012
Pertusillo_RA_HI-05	8	Jul 2011 – Feb 2013
Pertusillo_RD_HI-15	12	Dec 2012 – Mar 2013
Pertusillo_RD_HI-04	11	Feb 2012 – Oct 2012
Pertusillo_RD_HI-05	10	Apr 2010 – Nov 2012

Table 1. COSMO-SkyMed Datasets

Beam HIMAGE	Center Incidence Angle (deg)
H4_01	26.65
H4_03	29.36
H4_04	32.23
H4_05	33.97

Table 2. MapItaly beam

Potenza test area is a region about 30x30 km-wide in the Basilicata region (South part of Italy). The area of the town of Potenza(Fig. 2) is of high geophysical interest because it subject to landslides. Most of the territory of Potenza was formed in a structurally complex terrain which is particularly prone to slope instability phenomena because of its structural and lithological characteristics. Recent studies have shown that, in this area, most slopes show a tendency to landslide of various types and dimensions [5], [7] and [8], . Many of them are active and periodically cause serious widespread damage to things and sometimes to people. The analysis was carried out in a multi-image framework. 67 COSMO-skyMed SAR images over Potenza (with a maximum relative temporal baseline of more than 8 month and a maximum relative normal baseline of more than 200 m) were co-registered on a unique master taken on March 1, 2011. Aster DEM is used for compensation, 66 differential interferograms were generated. GIaNT Time Series chain used instead 272 Interferograms performing NSBAS Algorithm (Fig 2)

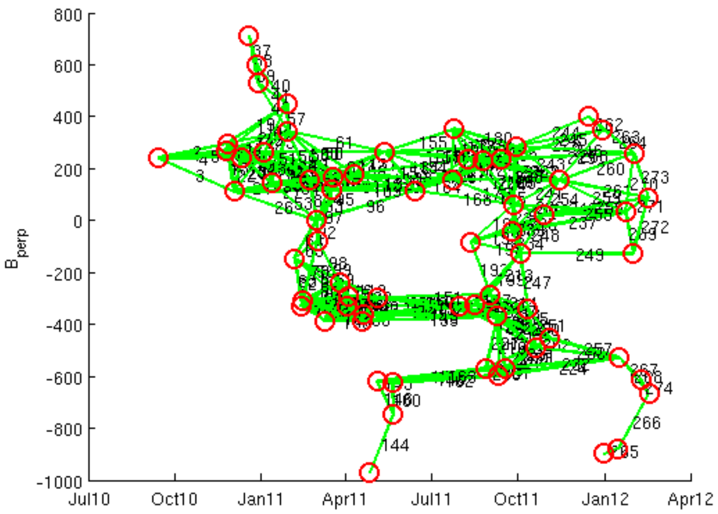

Figure 2. NSBAS temporal vs. perpendicular baseline plot

Pertusillo test site is a region of about 20x30 km-wide in the Basilicata region where 21 Oil field and Pertusillo dam are located. The Pertusillo dam is prevalently located on the Miocene sedimentary rocks of the Gorgoglione Flysh. The dam principally generates power and supply irrigation needs. It is a concrete arch-gravity dam 95 m high from the river bed. The crest length is 380m and the width on the foundation is about 40 m [4].

4. Results

The municipal area of Potenza was selected, as suitable to identify possible landslide according to ground truth acquired data. The interest in this territory mainly derives from its representativeness of the geomorphological and geological settings of landslide processes. The urban area of Potenza is located in Southern Italy (Fig. 1). It covers 174 km2 approximately. The area is a part of the Apennine Chain and has a mean annual rainfall of about 800 mm. Elevation varies from 593 to 1,339 m above the sea level. Most of the territory of Potenza was formed in a structurally complex terrain which is particularly prone to slope instability phenomena [5] because of its structural and lithological characteristics (Fig 3) [5], [7], [8] and [9]

Figure 4 Show PS Map overlapped to a Landslide inventory catalogue, Several landslide area covered by persistent scatterers can be identified. GIAnT and StaMPS together with GPS measurements and [10] have been used for a direct comparison

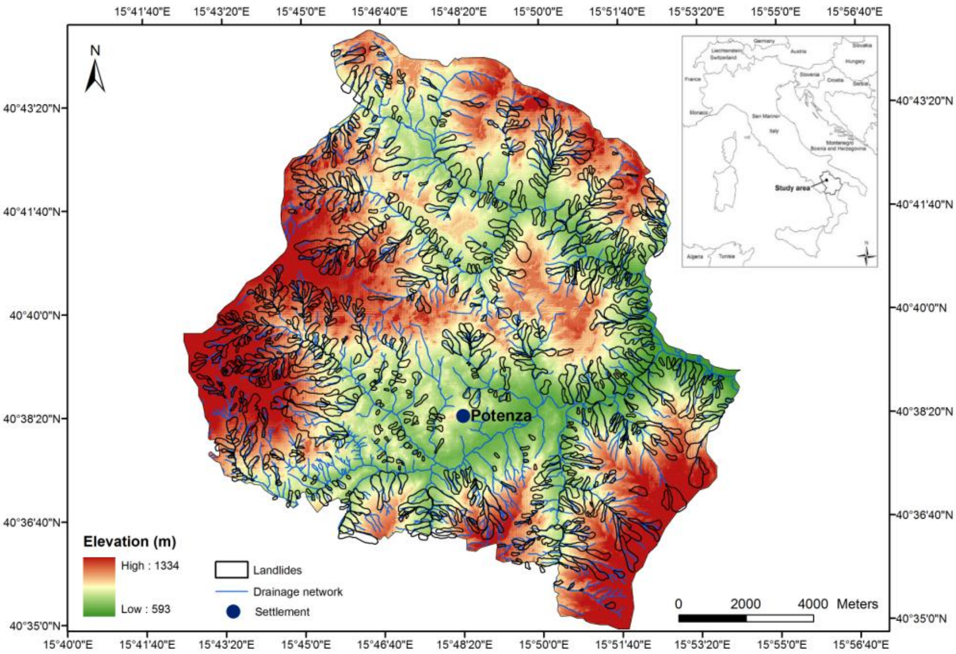

Figure 3. Landslide inventory map of the municipal area of Potenza

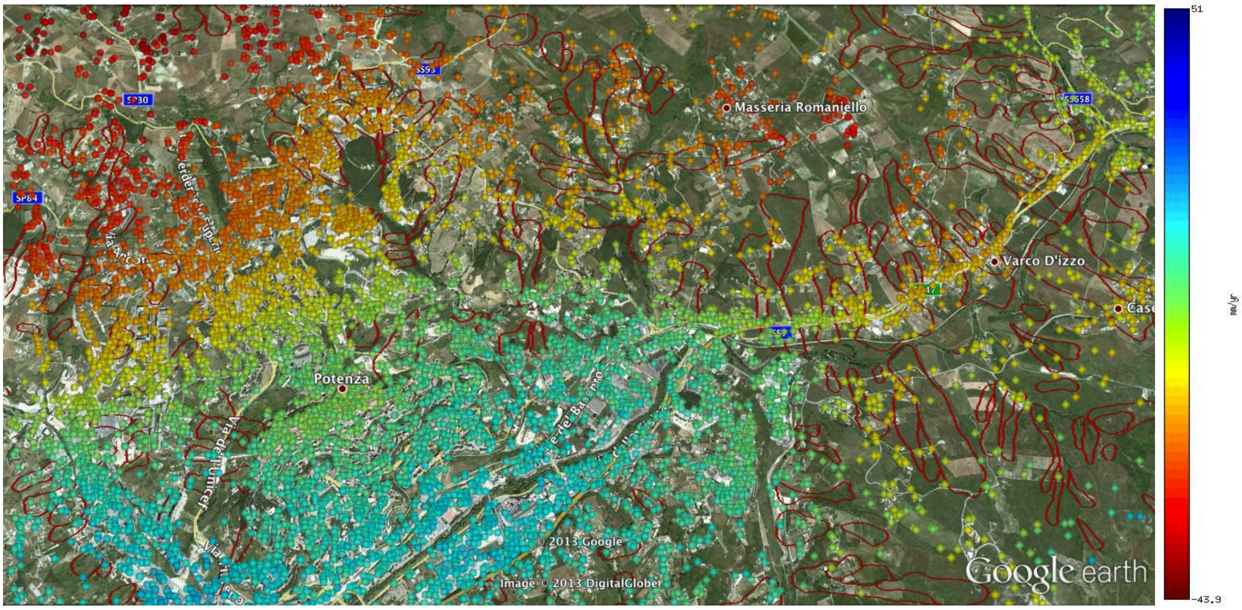

Figure 4. Potenza : PS - StaMPS analysis overlapped on landslides map

Pertusillo MapItaly Dataset show the potential of a short time InSAR acquisition in detecting seasonal movements like dam deformations due to the filling level of the basin. Moreover the wide coverage provided by this project allow an extensive analysis of the ground deformations with a finer spatial resolution typical of the X-band sensors. Figure 5 shows the velocity map calculated on the Pertusillo datasets.

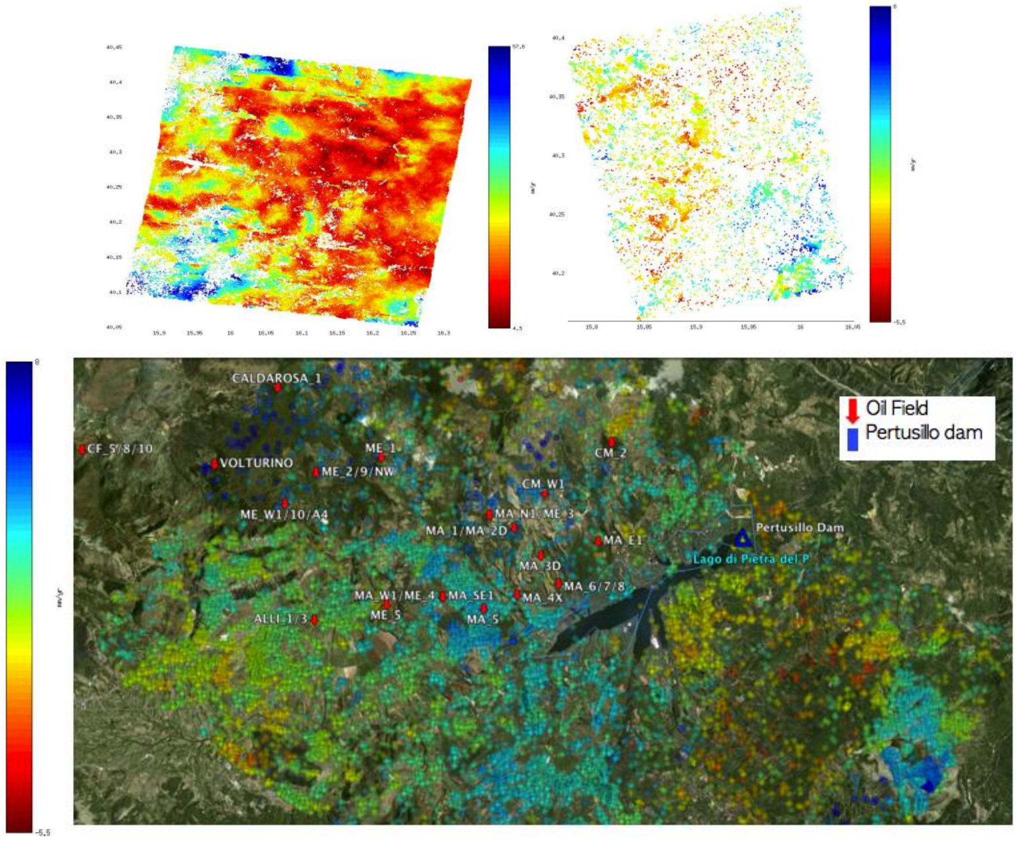

Figure 5. Pertusillo: PS analysis

5. Conclusions

We analyzed five COSMO-SkyMed datasets on Potenza and Pertusillo test site with the purpose of underlining the high capability of the system to provide short temporal time series.

Potenza test site revealed interesting results for what concern landslide detection during the period November 2010 – February 2012 [10], GPS measurements confirm the Trend monitored by SAR observations .

Pertusillo test site also revealed some interesting results but no definitive conclusion can be hypothesized according to the low number of SAR data available.

The high temporal resolution of the COSMO-SkyMed constellation promise to fill this gap in the next few months.

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